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Research Article

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Early Postoperative Clinical Observation of Arthroscopic Posterolateral (PL) Bundle Repair for Mild Anterior Instability of the Knee

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Abstract

Purpose: To explore the clinical effect of repairing the PL bundle stop point of the ACL ligament for mild anterior instability in the knee extension position.

Methods: 21 patients with mild anterior instability in the knee extension position underwent arthroscopic PL bundle repair of the anterior cruciate ligament femoral stop. The patients were followed up for 1 to 5 months after treatment, and the stability of the knee joint before and after treatment was evaluated.

Results: Among the 21 patients, 19 patients recovered the knee flexion and extension function within 4 weeks and 2 patients had knee joint function limitation when the knee flexion reached 90º. After 2 months, they underwent lower limb adaptive training; and after 4 months, they basically recovered the function of knee joint and started physical exercise. ①knee joint stability evaluation: Compared with the preoperative period, Lachman test was negative in the early postoperative patients and there was no significant change in the ADT test. Furthermore, postoperative MRI of the knee indicated that ACL signals were uniform and continuous. The tension of the ACL was significantly improved. ②knee joint function estimation: Compared with the preoperative level, the postoperative patients'scores of the IKDC test, Lysholm test, and Tegner test were significantly increased ($P<0.05$). All patients had no adverse reactions, such as infection, joint instability, and recurrence of ACL tear.

Conclusions: The PL bundle repair is a kind of ACL enhancement, which has many advantages, such as short operation time, less bleeding, accurate positioning, quick postoperative recovery, and fewer complications, and it does not affect ACL reconstruction when the ACL ruptures again.

Keywords: Partial anterior cruciate ligament injury; Knee instability; Anterior cruciate ligament repair; Arthroscopic

Introduction

Anterior Cruciate Ligament (ACL) injury is the most common ligament injury in the knee joint, and it often occurs in athletes, soldiers, and other groups engaged in high-intensity training [1]. In addition to complete rupture of the ACL (knee joint height instability) caused by the first acute trauma, many patients suffer from partial ACL injury (minor knee joint instability) due to repeated knee joint sprains. At the same time, some patients develop symptoms as the knee is unsteady in extension. Partial ACL injury will reduce the proprioception in the knee joint, increase the likelihood of sprain recurrence, and eventually lead to complete ACL rupture. The current "gold standard" for the treatment of ACL injury is arthroscopic ACL reconstruction [2]. However, donor site complications, graft failure, intra-articular infection, synovitis, traumatic arthritis, and other complications after ligament reconstruction are unavoidable [3]. Also, patients undergoing ACL reconstruction have a greater dissatisfaction rate and a lower probability of returning to training. Therefore, early diagnosis of mild anterior instability in the knee extension position and corresponding treatment can theoretically prevent complete ACL rupture, thereby avoiding surgery-related and rehabilitation-related complications experienced by the patients.

The clinical judgment of ACL injury mainly relies on the history of knee injury, clinical physical examination, and post-injury Magnetic Resonance Imaging (MRI) [4]. Such patients often experience knee sprains, occasionally accompanied by snapping, and knee joint swelling and pain after the injury. If the trauma is not caused by severe violence, the knee joint pain does not last long, and the swelling is resorbed within a few days. This is also the main reason why ACL injuries are often missed clinically. It is also based on the historical and social reasons for inadequate understanding of soft tissue injuries by sports medicine physicians working in the first-level and second-level hospitals in China. With vigorous development of sports medicine in the past decades, this phenomenon is gradually improving. Physicians working in all levels of hospitals have gradually deepened their understanding of ACL injuries. At the same time, MRI examinations have become more popular, and the missed diagnosis rate for acute ACL injuries has been decreasing every year. Therefore, as sports medicine physicians, in addition to judging acute and chronic complete ACL ruptures, we should also focus on the diagnosis and treatment of partial ACL injuries, which are more difficult to diagnose and more controversial [5,6].

The diagnosis of ACL injury is mainly based on the results of MRI images and clinical examinations, and the consistency between the two modalities [7]. According to the MRI examination, ACL injuries are mainly divided into the following three grades: Grade I injury, ligament signal disorder with the same length and tension of the ligament, with/without a small amount of effusion; Grade II injury, ligament signal disorder with changes in ligament length and tension, with/without moderate effusion, occasionally accompanied by grade I~IIdamage to the cartilage or meniscus; Grade IIIinjury, internal ligament signal disorder, blurred boundary, interrupted continuity, and occasionally accompanied by large amount of effusion or Posterior Cruciate Ligament (PCL) tortuosity, trauma-induced arthritis, and synovitis, i.e., acute or chronic manifestations of complete ACL rupture [8]. In patients with chronic pain in the knee joint after clinical trauma or pain during exercise, it is easy to miss the diagnosis and the diagnosis is controversial if partial ACL injury is judged only

by MRI. Therefore, the results of clinical examination are extremely important for judging ACL injury. Studies have shown that the Lachman test is more sensitive for the stability of the knee joint than the Anterior Drawer Test (ADT) **[4,9].** The Lachman test judges the degree of ACL injury at the following three levels: level I, tibia advancement 1~5 mm; level II, tibia advancement 6~10 mm, and then one can feel the obvious advance stop, which we termed Hard Stop; level III, the tibia advances more than 10 mm, but one cannot feel the obvious advance stop, which we termed Soft Stop **[10] (Figure 1).** We believe that if both MRI and Lachman test show grade II injuries, in combination with the patient's history of knee injury and persistent pain during exercise after injury, the diagnosis of partial ACL injury, i.e., mild anterior instability of the knee joint, is clear. Therefore, the author performed arthroscopic ACL repair in patients with partial ACL injury, and early postoperative follow-up achieved good results. The report is presented below.

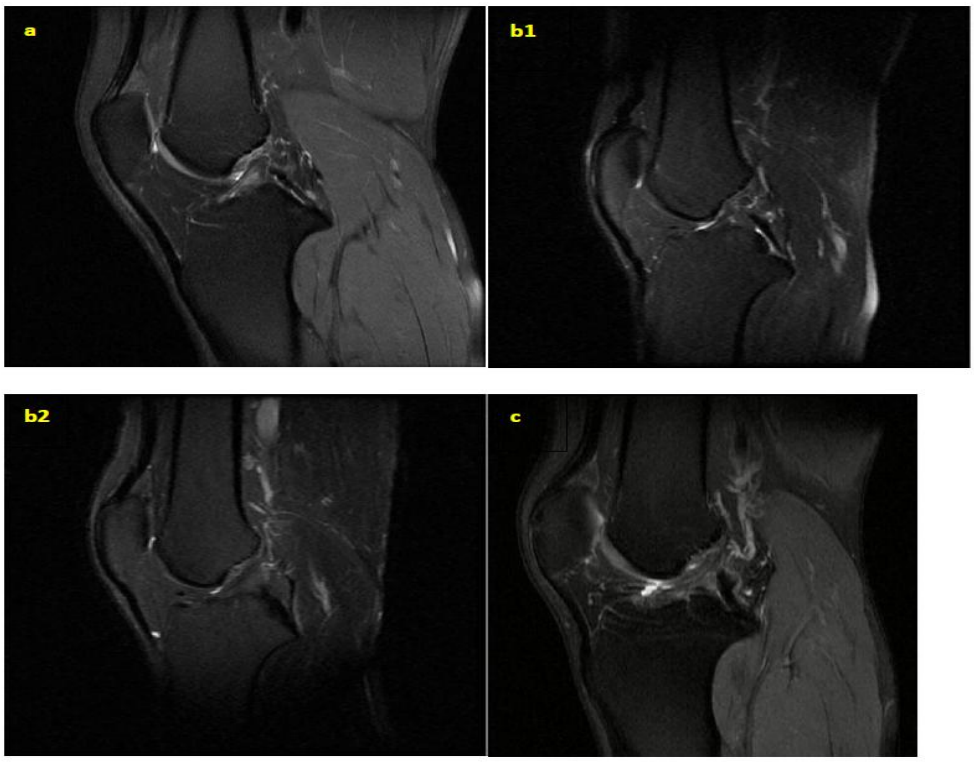

Figure 1: The degree of ACL injury: a) level I, the width of the ACL becomes thinner and the color is dull, but the length and tension remain unchanged; b) level II, same patient. b1: the length and tension of the ACL are changed to be parallel to Blumensaat's line, b2: a normal ACL; c) The length and tension of the ACL are changed and anterior tibia.

Materials and Methods

General information

The subjects were 21 patients (21 knees) diagnosed with mild anterior instability of knee joints by the same sports medicine professional in General Hospital of the PLA Northern Theater Command from March 2020 to November 2020. All patients (25.3±9.7 years old) had mild knee trauma and mild swelling of the knee after injury, and the diagnosis was not confirmed by the first-time physician. The preoperative physical examination showed mild instability of the knee joint, and all the subjects underwent arthroscopic surgery from the same surgeon. Preoperative MRI and physical examination showed mild anterior instability of knee joints, and all

patients underwent arthroscopy from the same surgeon.

Supplementary examinations

①Direct sign: MRI of the ACL showed a continuous but thickened ACL (T1); ACL tension changes and degeneration; PCL tortuosity and other signals (T2), **(Figure 2).** ②Indirect sign: MRI examination showed meniscal injury and degeneration, and bone contusion of the supracondylar femoral region; and X-ray examination showed bone hyperplasia over the intercondylar eminence.

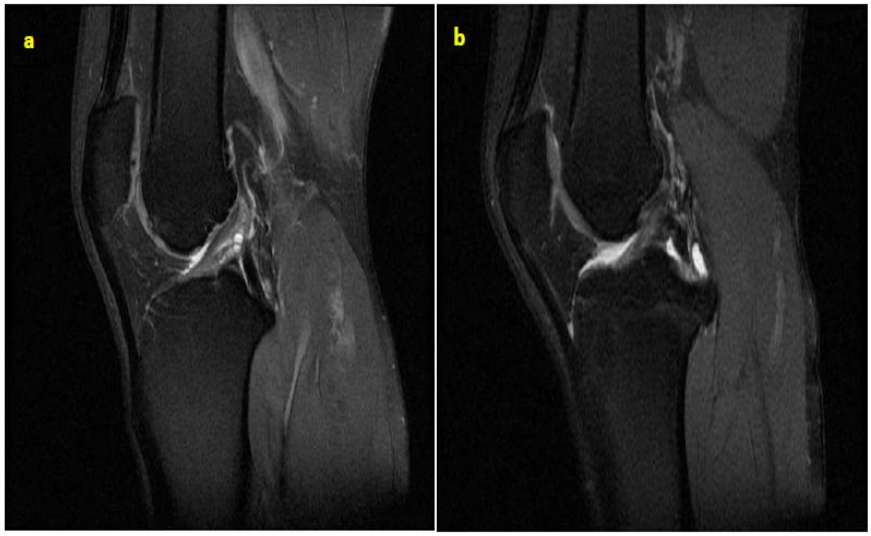

Figure 2: MRI showed partial ACL injury to left knee. a) ACL tension changes and PCL tortuosity; b) ACL degeneration and effusion in the intercondylar fossa.

Physical examination

The assessment of mild knee instability: negative ADT test (knee flexion 90º), Hard stop positive Lachman test (knee flexion 30º), and negative or first degree positive axis shift test (iliotibial band friction).

Inclusion criteria

①several-year history of high intensity exercise or mild trauma;②unilateral ACL injury, the contralateral knee joint was normal and the affected side was not consistent; ③clinical manifestation was knee joint pain during exercise or "giving way"; ④after auxiliary examination and physical examination were performed as mentioned above; ⑤MRI manifested ACL signal disorder, but there was still a certain degree of continuity, which can be accompanied by PCL tortuosity; ⑥patient informed consent for treatment.

Exclusion criteria

①knee joint hyperextension (＞5º); ②MRI indicated complete ACL rupture; ③Physical examination revealed that the knee joint was highly unstable: ADT test was positive (the anterior tibial movement distance was greater than 5 mm with knee flexion 90º), Lachman test with Soft Stop was positive (knee flexion 30º), and axial shift test was positive (iliotibial band snapping); ④patients with basic diseases and poor general conditions, as well as those with mental and psychological diseases who could not cooperate with doctors.

Operation method

After general anesthesia, the patient's knee Lachman test was reexamined. All patients were treated with 90° knee flexion stents without tourniquet. Arthroscopy was performed to examine the intra-articular condition under the conventional approach of the medial and lateral patellar ligaments. The flexion and internal rotation of the knee (Patrick sign) elongated the ACL, examined the texture and tension of the ACL, and evaluated the ACL injury at the femoral attachment site **(Figure 3).** If the Posterolateral (PL) bundle of the ACL was significantly relaxed and atrophic, the PL bundle femoral attachment site was exposed after cleaning the hyperplastic synovial membrane, and a 3.5 mm anchor was implanted at the femoral attachment site of the PL bundle after moderate polishing with a grinding drill. The PL bundle stump was sutured and knotted in the knee joint extension position so that the PL bundle stump was firmly fixed in its anatomical position **(Figure 4).** The Lachman test of the knee was performed again after the operation, and if it was negative, it proved that PL bundle repair was effective.

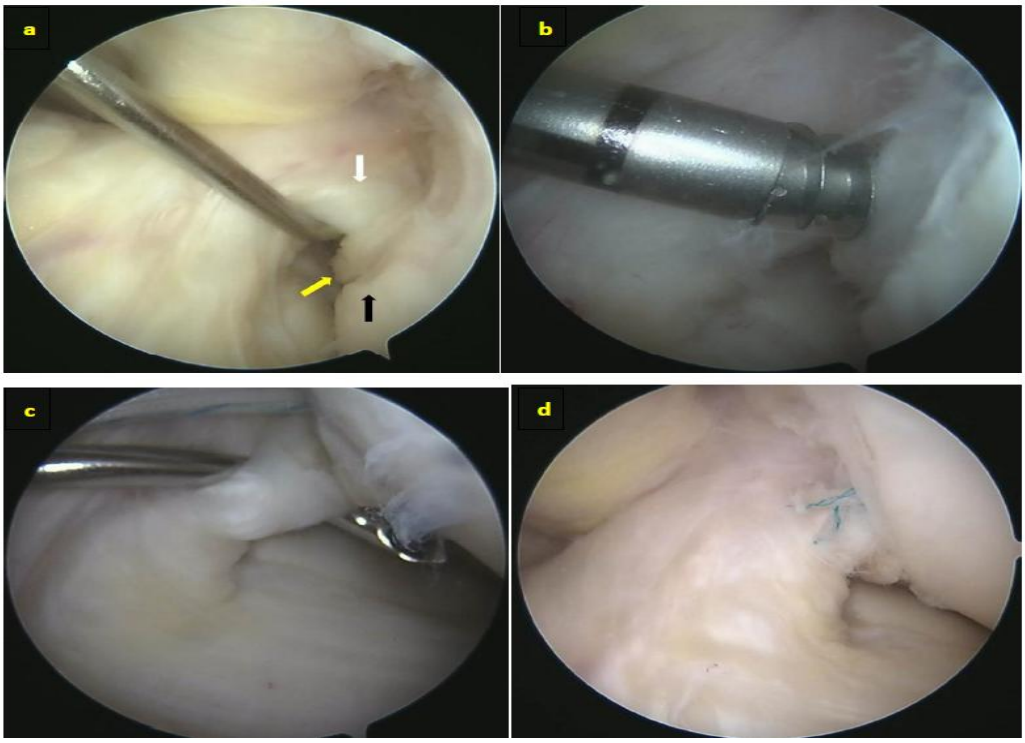

Figure 3: The ACL of the left knee is shown arthroscopically， the patient is a 40-year-old male who is engaged in a fatigued sports occupation. a) White arrow: PL bundle relaxation, Yellow arrow: yellow synovium of compensatory hyperplasia of femoral anchorage point of PL bundle, Black arrow: Osteophytes with hyperplasia of the lateral femoral condyle (indirect signs); b) insert a threaded screw at the PL bundle femoral anatomical stop; c) find the shrinking and loose PL bundle; d.after suture repair,the tension of the repaired ACL is satisfactory.

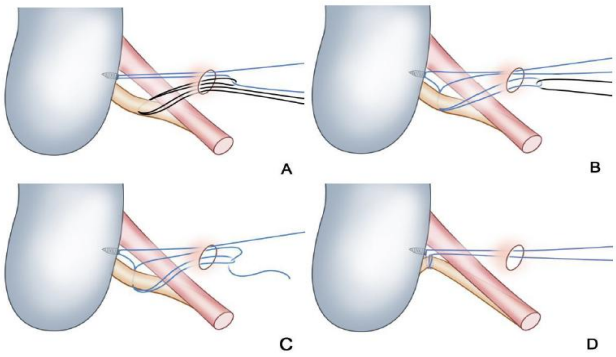

Figure 4: The PL bundle stump was sutured and knotted in the knee joint. a) Insert a 3.5mm wire anchor at the femoral anchor point of the PL bundle; B,C) Suture the PL bundle stump; D.Knot in the knee extension position.

Rehabilitation program

Prophylactic antibiotics were administered on the second day after the operation, and drugs were given for symptomatic treatment. The hinge brace of the knee joint was adjusted so that the knee could move within the 0°~45° range. No weight bearing was allowed for 2 weeks; only quadriceps isometric contraction and straight leg raising training were performed. After 2 weeks, the affected limb could carry partial weight, and the flexion angle was increased by 10° per week. After 6 weeks, the affected limb could carry full weight.

Evaluation standard

To compare the stability and function of the knee joint before and after the operation, the following assessments were performed. ①knee joint stability evaluation: Lachman test, Anterior drawer test (ADT); ②knee joint function estimation: International Knee Documentation Committee (IKDC) test, Lysholm test, and Tegner test **[11-14].**

Statistical analysis

SPSS 22.0 was used for statistical analysis. Statistical data were compared by chi-square test, measurement data were compared by T-test, and the test level was $\alpha=0.05$ ($P<0.05$ indicated a significant difference).

Results

A total of 21 patients (21 knees) were included in the study, and complete postoperative follow-up was conducted (minimum 1 month, maximum 5 months). Among the 21 patients, 19 patients recovered the knee flexion and extension function within 4 weeks and 2 patients had knee joint function limitation when the knee flexion reached 90º. After 2 months, they underwent lower limb adaptive training; and after 4 months, they basically recovered the function of knee joint and started physical exercise. ①knee joint stability evaluation: Compared with the preoperative period, Lachman test was negative in the early postoperative patients and there was no significant change in the ADT test. Furthermore, postoperative MRI of the knee indicated that ACL signals were uniform and continuous. The tension of the ACL was significantly improved **(Figure 5).** ②knee joint function estimation: Compared with the preoperative level, the postoperative patients' scores of the IKDC test, Lysholm test, and Tegner test were significantly increased ($P<0.05$), as shown in **Table 1**. All patients had no adverse reactions, such as infection, joint instability, and recurrence of ACL tear.

Table 1: **K**nee joint function estimation (`x±s).

	preoperative	After two months postoperatively
IKDC test	67.95±4.37	77.82±5.71*
Lysholm test	69.62±5.12	80.32±6.15*
Tegner test	6.24±1.11	7.41±1.38*

Table note: Compared with the preoperative scores, the IKDC, Lysholm, and Tegner scores of postoperative patients were significantly increased (*P＜0.05).

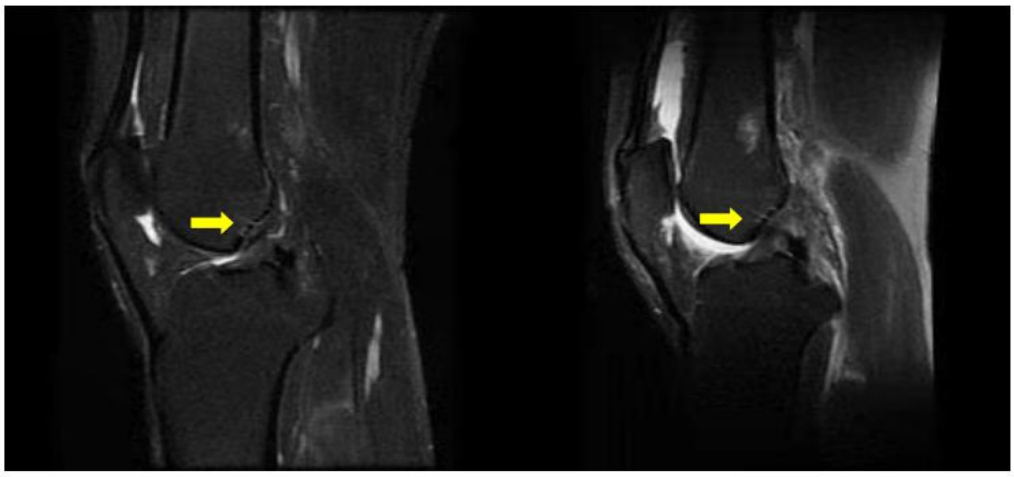

Figure 5: In the preoperative and postoperative sagittal ACL changes. a) Parallel to the Blumensaat's line before surgery; b) non-parallel to the Blumensaat's line after surgery).

Discussion

It is now generally recognized that the native ACL does not behave as a simple band of fibers with constant tension. The separation of this ligament into Anteromedial (AM) and PL fiber bundles has now been widely accepted as a basis of understanding of ACL function **[15]**. Different effects of each bundle on tibial rotation and translation were described and different tensioning patterns were observed throughout the full range of knee flexion. The AM bundle better restrains anterior tibial translation at greater than 45º of knee flexion, whereas the PL bundle has been shown to be less isometric and a more important restraint toward full extension **[16,17].** This biomechanical theory can only explain the anterior instability of the knee joint in the extended state noted by the author in clinical observations, i.e., the PL fiber bundle in the extended position exerts the main stabilizing effect, and the AM fiber bundle exerts the main stabilizing effect when the knee is bent. Therefore, the asymmetric Lachman test is positive, but the ADT test and the axis shift test are negative. At the same time, this also shows that the anterior instability during knee extension is the clinical symptom of simple PL bundle

failure. This symptom mainly includes positive Lachman test with Hard Stop, but a negative axis shift test. Of course, arthroscopic findings are also necessary for establishing the diagnosis of anterior instability (PL fiber bundle failure) during knee extension.

The fiber shape of the PL bundle can be intuitively judged during arthroscopy, but because the PL bundle is covered by the AM bundle, it is not easy to determine PL bundle injury during the operation. The PL bundle can be more easily identified when the knee is placed in the figure of four position. Our judgment of PL bundle failure under arthroscopy is mainly based on its manifestations, such as creep, atrophy, slack, or rupture. According to our experience, if the PL bundle is found to be significantly slack in the ”4 position” (a position like Patrick sign), PL bundle failure can be clearly diagnosed. In addition, partial ACL injury can also show certain manifestations in MRI images. In a French study [18], 195 files with complete MRI were collected for analysis. On sagittal 188 sections, we described the following three types of ACL fiber lesions: “disorganized 189 fibers”, when the fibers did not have any structural aspect or had disappeared, “straight fibers” , when the fibers had longitudinal orientation parallel to the Blumensaat’s line , and the third type was “lying down fibers” when the remaining fibers were lying down in the intercondylar notch close to the PCL. In the preoperative and postoperative sagittal ACL changes shown by the author, we can see that the ACL changed from parallel to the Blumensaat’s line before surgery to non-parallel to the Blumensaat’s line after surgery, indicating that ACL repair has effectively improved the ACL tension **(Figure 5).** Studies have found that about 10%-25% of patients with ACL injury have pure AM or PL bundle damage, and the PL fiber bundle is more sensitive and more vulnerable than the AM fiber bundle. It is especially common in patient groups which have experienced large amounts of exercise for a long time, such as athletes and military personnel. Patients often suffer from fatigue during training, and even minor sprains can lead to cumulative ACL damage. If left untreated and if the patients continue to exercise, it may eventually lead to complete ACL rupture **[19].** In 2013, Ashton-Miller found through a biomechanical study of a human cadaveric knee joint model that jumping and falling movements with repeated pressure application can easily cause ACL fatigue damage. However, Miller's research was only an in-depth study of biomechanics and the clinical research was not performed **[20,21].** Dhillon MS analyzed the risk of cruciate ligament damage based on the changes in the mechanoreceptors of the cruciate ligament **[22,23].** His research found that the number of proprioceptors changes with the length of ligament damage. The longer the damage, the fewer the number of proprioceptors; thereby increasing the risk of ACL damage. We have also encountered such patients in the clinic. At the time of initial diagnosis, they showed mild anterior instability when extending the knee. The patients did not stop training, but after more than 1 year of follow-up, the patients eventually developed complete ACL rupture.

In complete ACL rupture, the selection of appropriate grafts for ACL reconstruction is the "gold standard" for the treatment. In partial ACL injury, the application of ACL repair is controversial, mainly because of the higher rerupture rate reported in clinical studies. ACL repair has a long history. It was first carried out in 1895 by Mayo, a scholar in Leeds, England, and it became the "gold standard" for ACL injury treatment in the 1970s and 1980s **[24].** However, due to the high rate of rerupture after a 5-year follow-up, ACL reconstruction was gradually replaced. However, the author believes that the more popular ACL repair surgery in the last century was mainly applied in complete ACL rupture, and the surgical method was incision. Under the historical conditions of the year, a higher rate of rerupture can be expected. In recent years, with the popularization and precision of arthroscopic technology, and gradual deepening of the academic understanding of partial ACL

injury, ACL repair has an opportunity to play its role again. The author's research method is mainly aimed at partial ACL injury during knee extension. Such patients mainly suffer from PL bundle injury. The purpose of this study was as follows: on the one hand, the repair of the PL bundle can strengthen the AM bundle; on the other hand, because the fibrous tissue of the ACL contains blood vessels and a large number of mechanoreceptors, the tension and continuity after repairing the PL bundle are conducive to the recovery of knee joint proprioception **[25,26].** The combined effect of the two can effectively avoid complete ACL rupture. From the results of this study, it can be determined that most of the patients undergoing ACL repair have satisfactory recovery results and the range of knee joint flexion and extension activities after ACL repair is not significantly affected. The effect of early treatment is particularly noteworthy. In all patients, mild anterior instability during knee extension changed from a positive Lachman test with Hard stop before surgery to a negative Lachman test postoperatively. In addition, after our consideration, if the ACL ruptures again after repair, the choice of the femoral tunnel when ACL reconstruction is required will be closer to the anatomical position of the AM bundle. Therefore, we select patients with pure PL bundle injury for performing ACL repair to avoid interference with the AM bundle femoral point. Therefore, the theoretical basis of our study is not to repair pure AM bundle injury.

In summary, for the treatment of anterior instability during knee extension, the inclusion criteria should select the group with high intensity, large amount of exercise and knee pain during exercise. At the same time, it is necessary to have symptoms of unstable knee extension, such as positive Lachman test with Hard stop. Routine arthroscopic examination was first performed during the operation, and partial ACL injury was diagnosed through the relaxation, contracture, and compensatory synovial hyperplasia of the PL bundle under the "4-position" of the knee joint. The PL femoral anatomical stop point was immediately peeled off to freshen the bone surface, a threaded anchor or knotless anchor was implanted to suture the PL stump to the anatomical stop, and then the Lachman test was performed to determine the suture effect. The PL bundle repair proposed by the author is a kind of ACL enhancement, which has many advantages, such as short operation time, less bleeding, accurate positioning, quick postoperative recovery, and fewer complications, and it does not affect ACL reconstruction when the ACL ruptures again. Twenty-one patients (21 knees) in this study 258 were followed up until the present time, and there were no adverse reactions, such as infection, pain, and joint instability after the operation, and satisfactory early clinical results were obtained. However, the shortcoming is lack of long-term clinical follow-up, and the overall 5-year rerupture rate and the probability of complete rupture need further observation.

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